RHEOLOGICAL CHARACTERISTICS OF DOUGH ENRICHED WITH CAROB AND SUGAR BEET FIBRES

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ABSTRACT

A well-balanced diet with a focus on increasing consumption of complex carbohydrates with a low glycemic index is a major nutritional goal to improve public health. Daily intake of dietary fibres is significantly lower than the recommended 25 g which resulted in the development of new functional products rich in fibre. The addition of fibres in bread as a daily most consumed foodstuff and integral part of at least two meals would provide an adequate intake of dietary fibres, and therefore all the associated positive physiological effects.
This study was focused on the effects of supplementation of carob flour and sugar beet fibre on the empirical dough rheology. Experiments were planned according to Box-Behnken experimental design, with independent variables: quantity of carob flour (0, 10 and 20% on flour basis), quantity of sugar beet fibre (0, 3 and 6% on flour basis) and quantity of preservative (0, 0.2 and 0.4% on flour basis).
Significant increase in farinograph water absorption by 25% and dough development time by 85% was obtained by incorporating 6% of sugar beet fibres when compared to control sample. It was also observed that the addition of sugar beet fibres led to a significant reduction in the degree of softening which is a consequence of the ability of fibres to bind and retain water. In the dough with 20% of carob flour was reported a significant increase in dough energy for about 35% followed by the pronounced increase in dough resistance to extension and decrease in dough extensibility when compared to control sample. The most pronounced trend in the increase of dough resistance to extension and decrease of dough extensibility was observed in the samples with both carob flour and sugar beet fibres included in the formulation.

Keywords: *carob flour, sugar beet fiber, dough rheology*

INTRODUCTION

Dietary fibre is considered as one of the food ingredients with a significant contribution to health. Physiological properties of dietary fibres are associated with prevention of certain diseases such as: obesity, type 2 diabetes, hypertension, cardiovascular diseases and some types of cancer (Kendall *et al*., 2010). The stated link between the intake of dietary fibres and mentioned health benefits has prompted the interest in fibre-enriched baked products. Numerous researchers have been focussed on the development of fibre-enriched bakery products in an attempt to overcome the challenges of the different fibre effect on gluten network in order to produce acceptable product which meet the consumers demand.

Various different fibres can become inputs for the manufacture of fibre-enriched bread. Carob flour obtained by milling after the isolation of locust bean gum from carob seed is considered as a by-product and can be used in the food industry. Addition of carob flour, as a significant source of protein, high amounts of dietary fibre and micronutrients, to the fibre-enriched bread can enhance the overall nutritional value of the bread (Tsatsaragkou *et al*., 2012). Moreover, due to the relatively high ratio of total and soluble dietary fibres, low amount of lipids and low energy value, sugar beet fibres offer excellent food processing characteristics and physiological benefits to the food producers and consumers (Ozboy and Koksel, 2000). The main goal of sugar beet fibres application in the production of baked products is the improvement of nutritional effect and the technological quality of the final product (Sekulić *et al*., 1992).

The significance of rheology in bread preparation has been the subject of many studies whose results are well documented (Debraszczyk and Salmanowicz, 2008; Ktenioudaki *et al*., 2010; Stojceska *et al*., 2007). The addition of dietary fibres in bread-making has great influence on dough rheological properties and dough handling. Dietary fibre incorporation into wheat dough greatly interferes with the gluten network as fibres occupy the space of the proteins causing its dilution (Rosell *et al*., 2010). The effects of added fibres are determined by type and physicochemical properties of fibres as well as their quantity (Ktenioudaki and Gallagher, 2012).

Therefore, when potential use of fibres is considered for enrichment of bread it becomes necessary to assess the impact of fibres on bread dough rheology. The objective of this study was to understand the individual and combined effects of the supplementation of carob flour and sugar beet fibre on the empirical dough rheology.

MATERIAL AND METHODS

For all tests commercial wheat flour type 500 was used with moisture content 13.3%, 11.1% proteins, 0.46% ash, 1.1% fat and total dietary fibre 3.1%. Carob flour (provided by Mlinotest, Slovenia) and sugar beet fibre were used to make dietary fibre-enriched dough. Sugar beet fibres were obtained after treatment with hydrogen peroxide solution (H_2O_2, concentration of 30%), followed by the successive and gradual addition of 10 mol L-1 NaOH in the reaction mixture until pH=11 was reached. 24 h after the chemical treatment mixture was neutralised with cc HCl until the pH value was between 6 and 7, rinsed with distillate water, pressed, dried in convective dryer at 65°C and milled on a laboratory mill (Foss Knifetec 195, Denmark). Sugar beet fibres with particle size less than 315 μm were used in further rheological tests.

Wheat flour was replaced by carob flour, sugar beet fibres and their combination according to Box-Behnken experimental design, with independent variables: quantity of carob flour (0, 10 and 20% on flour basis), quantity of sugar beet fibre (0, 3 and 6% on flour basis) and quantity of preservative (sodium propionate) (0, 0.2 and 0.4% on flour basis) (Table 1).

Table 1. Plan of experiment according to Box-Behnken experimental design

Run	Independent variables		
	Sugar beet fibres (%)	**Carob flour (%)**	**Preservative (%)**
1	0	0	0
2	0	0	0.4
3	0	20	0
4	0	20	0.4
5	0	10	0.2
6	6	0	0
7	6	0	0.4
8	6	20	0.4
9	6	20	0
10	6	10	0.2
11	3	0	0.2
12	3	20	0.2
13	3	10	0
14	3	10	0.4
15	3	10	0.2

The effect of the carob flour and sugar beet fibres on dough rheology during mixing was determined by a Brabender Farinograph (300-g flour capacity) (Brabender, Duisburg, Germany), following the AACC 54-29. The determined parameters were: water absorption (WA, %), dough development time (DDT, min), stability (ST, min), degree of softening (DS, BU) and Farinograph quality number/class. For extension tests dough was prepared using the Farniograph (300-g flour capacity). The extension tests were conducted in accordance with the standard procedure (AACC 54-10), using the Brabender Extensograph (Brabender, Duisburg, Germany). The following parameters were determined: energy (E, cm^2), resistance to extension (R, BU), extensibility (Ex, mm), and ratio number.

RESULTS AND DISCUSSION

Effect of carob flour and sugar beet fibres on farinograph parameters

The addition of carob flour and sugar beet fibres promoted differences on the dough mixing behaviour measured by the farinograph. In Figure 1 are presented farinograph parameters (water absorption, dough development time and degree of softening) that are most affected by incorporation of carob flour and sugar beet fibres in fibre-enriched dough.

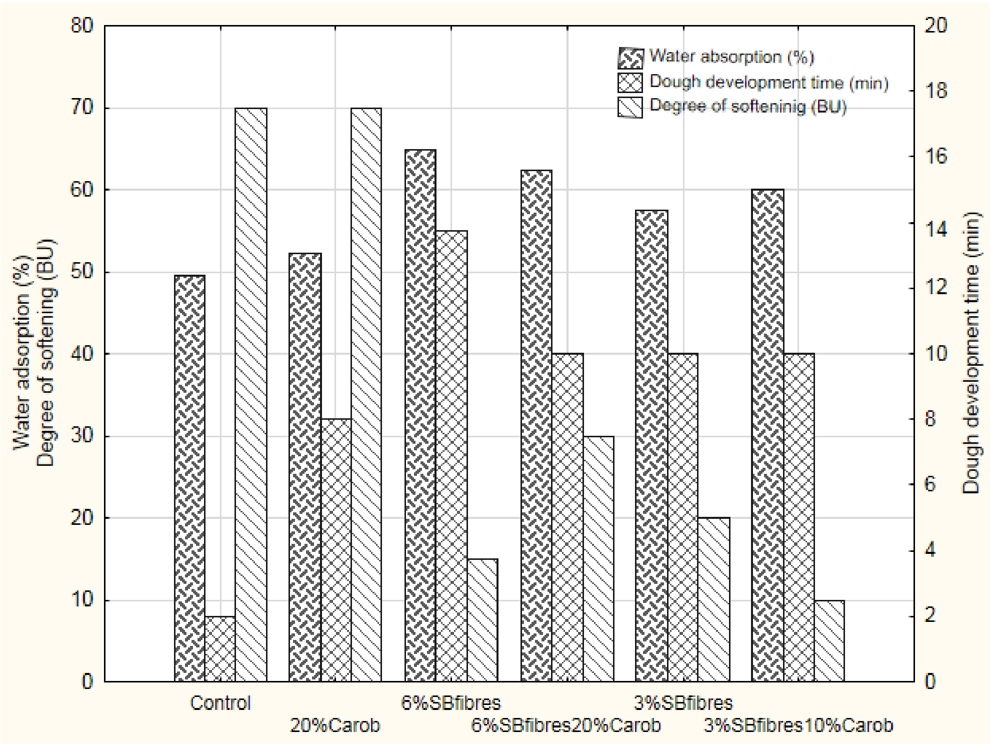

Figure 1. Effect of carob flour and sugar beet fibres on farinograph parameters

Addition of carob flour and sugar beet fibres mainly modified the farinograph water absorption. The significant increase in water absorption of 25% and 20% was found with the addition of 6% sugar beet fibres and combination of 20% carob flour/6% sugar beet fibres, respectively. The addition of 20% carob flour also increased the water absorption but in smaller extent (Figure 1). Furthermore, the obtained results showed that sugar beet fibres had more pronounced effect on water absorption and that with increasing amounts of sugar beet fibres water absorption also increased. This ability of dietary fibres to absorb considerable amounts of water is mainly determined by the presence of a large number of hydroxyl groups in fibre structure which enter into interactions with water via hydrogen bonds (Rosell *et al*., 2001). Dough development time and stability values were also modified with addition of carob flour and sugar beet fibres. The highest extension of the dough development time (by 85%) was achieved by incorporating 6% of sugar beet fibres. The trend of dough development time extension by 80 and 75% was also observed with addition of 20% carob flour/6% sugar beet fibres in combination and 20% carob flour, respectively

(Figure 1). Extension of dough development time may be associated with the interaction that occurs between dietary fibres and gluten proteins as they are competing for available water and thus, fibres inhibit gluten hydration and development (Gomez *et al*., 2011). A slight increase in dough stability was noticed with addition of 20% carob flour and 6% sugar beet fibres while the combination of 20% carob flour/6% sugar beet fibres led to the greatest increase in the mentioned parameter. The results of previously conducted studies showed that the addition of dietary fibres had either no influence or increased the dough stability which can be explained by a stronger interaction between dietary fibres, water and flour proteins (Borchani *et al*., 2011). Degree of dough softening was not affected by incorporation of carob flour, while the addition of sugar beet fibres led to a significant reduction in values of this parameter. The addition of sugar beet fibre (3%, 6%) decreased the degree of softening by about 70-80% when compared to control sample. This decrease was a consequence of the ability of sugar beet fibres to bind and retain bonded water (Rosell *et al*., 2006) during dough handling and thus, make a better water link in dough with a corresponding effect on the degree of softening. The farinograph quality number/class was enhanced by addition of sugar beet fibres while with incorporation of carob flour this parameter remained unchanged.

Effect of carob flour and sugar beet fibres on extensograph parameters

When analysing the extensograph parameters of fibre-enriched dough, significant changes in all determined parameters were observed (Table 2). Significant increase in dough energy was observed in all samples with carob flour and the highest of about 35% was reported in dough with 20% carob flour. An opposite effect was noticed with addition of sugar beet fibres. Incorporation of both carob flour and sugar beet fibres in fibre-enriched dough also affected values of dough energy. This effect depended on the combinations of additions in such a way that greater amounts of carob flour and sugar beet fibre in combination resulted in a slight dough energy increase while the smaller amounts led to significant increase in this parameter (Table 2). Addition of fibre from a range of sources decreases the dough extensibility, as shown in previously conducted studies, whereas it had a variable effect on the resistance to extension (Ktenioudaki and Gallagher, 2012). Significant increase in dough resistance to extension and decrease in dough extensibility were reported for all samples with carob flour at 10%, 20% replacement levels. The same effect was observed with the addition of sugar beet fibres at 3%, 6% replacement levels, while the most pronounced trend in the increase of dough resistance to extension and decrease of dough extensibility was observed in the samples with both carob flour and sugar beet fibres included in the formulation (Table 2).

Table 2. Effect of carob flour and sugar beet fibres addition on extensograph parameters of fibre-enriched dough

Run	Fibres (%)	Carob (%)	Preservative (%)	Energy (cm^2)	Resistance to extension (BU)	Extensibility (mm)	Ratio number
1	0	0	0	142.9	530	152.0	3.49
2	0	0	0.4	143.3	520	157	3.31
3	0	20	0	196.4	920	90	10.22
4	0	20	0.4	272.2	990	95	10.42
5	0	10	0.2	170.2	760	110	6.91
6	6	0	0	101.0	890	82	10.85
7	6	0	0.4	106.2	830	90	9.22
8	6	20	0.4	155.7	1000	38	26.32
9	6	20	0	148.8	1000	45	22.22
10	6	10	0.2	134.0	900	54	16.67
11	3	0	0.2	81.9	770	102	7.55
12	3	20	0.2	120.8	>1000	65	16.31
13	3	10	0	183.6	>1000	84	12.86
14	3	10	0.4	189.0	1000	85	11.76
15	3	10	0.2	200.8	>1000	75	15.3

Greater amounts of carob flour and sugar beet fibre added in combination led to increase of dough resistance to extension for about 45% and decrease in dough extensibility for 75%. The interactions between the carob flour and sugar beet fibre polymers cross-links can be a possible explanation of increased dough strength and resistance to extension, while significant decrease in dough extensibility clearly demonstrates that the addition of both carob flour and sugar beet fibres negatively affects the gluten network since the extension property is enabled by the presence of gluten complex proteins. As a consequence of changes in dough resistance to extension and extensibility significant increase in values of ratio number were observed (Table 2). Moreover, the ratio number values increased with an increasing percentage of carob flour and sugar beet fibre replacement.

CONCLUSIONS

Based on the results of evaluation of the farinograph and extensograph parameters of fibre-enriched dough prepared with addition of 10%, 20% carob flour and 3%, 6% of sugar beet fibres it can be stated that the addition of fibres affected the rheological behaviour of dough during processing. Farinograph water absorption significantly increased with increasing amounts of sugar beet fibres. As a general and common effect, both carob flour and sugar beet fibres extended dough development time due the competition for water between fibres and gluten. The combination of 20% carob flour/6% sugar beet fibres led to the greatest increase in dough stability. A significant reduction in the degree of dough softening occurred with addition of sugar beet fibres while this parameter was not affected by incorporation of carob flour. Farinograph results indicated that fibres had a weakening effect on dough and optimum dough development required an increase in the quantity of water and mixing time. The greatest increase in extensograph dough energy was reported with addition of 20% carob flour followed by addition of 10% of carob flour and 3% sugar beet fibre in combination. An opposite effect on this parameter was observed with addition of sugar beet fibres. A significant increase in dough resistance to extension and decrease in dough extensibility were reported for all samples. The highest increase in dough resistance to extension for about 45% and decrease in dough extensibility for 75% were observed with addition of 20% carob flour/6% sugar beet fibres.

The obtained results drive on to conclude that it is of great importance to define the effects of added fibres on dough rheology. Therefore, it is necessary to have a holistic concept when developing a new functional fibre-enriched product considering, type, source and quantity of added fibres.

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